

past, or on the point of coming to a conclusion, and in all cases the general tendency of the long period curve is now to rise again. This indication of the increase of the rainfall is represented in the figure by the dotted continuation of the secular variation curves for each station, and should the apparent law hold good, there seems sufficient evidence to mark that this rise will continue to take place until about the year 1913, which year will suggest the middle of the next wet epoch.

It may be mentioned, however, that owing to the great oscillatory nature of the rainfall from year to year, this rise only represents the mean rise when several years are coupled together; there may be comparatively dry years even when the secular variation curve is at a maximum, but on the average they will probably be wet.

What causes this long period of weather variation is not yet definitely known, but it is of the highest importance to meteorological science that the matter should be cleared up as soon as possible, for not only is our rainfall involved, but all other meteorological elements show similar fluctuations.

Brückner attempted to account for this long period weather cycle by attributing its origin to a change in the activity of the sun, and he investigated the sunspot data then available for evidence of a periodicity of about thirty-five years. He was not, however, successful in his research, but he concluded that, although this variation must really exist in the sun, yet it might not necessarily be indicated by sunspots. More recently a minute examination of the sunspot observations made since the year 1832, when a systematic method of observation had been initiated, has led to the discovery of such a period, a detailed account of which appeared in a previous number of this Journal (*NATURE*, vol. lxiv, p. 196). It was there shown that each sunspot period (reckoning from minimum to minimum) differed in many respects from the one immediately preceding or following it. Some periods, for instance, were not only more "spotted" than others, that is, the summation of the whole spotted area from one minimum to the next varied regularly, but these particular periods were closely associated with comparatively rapid rises from minimum to maximum in those periods. These changes further seemed to be undergoing a regular variation, the cycle of which was determined to be about thirty-five years.

The connection between Brückner's cycle and this long period solar change of thirty-five years was there briefly stated, and it was shown that at those two epochs of sunspot minima, namely, 1843 and 1878, which follow the cycles of greatest spotted area, the Brückner rainfall cycle was at a maximum.

The close correspondence of the epochs of these two cycles suggested at once a probable cause and effect, a cause which Brückner himself had suggested and looked for, but unfortunately did not find.

In the accompanying figure the uppermost curve represents the sunspot curve from the year 1832, and the minima just referred to are indicated by the vertical dotted lines, which are continued through all the curves. The periods of greatest spotted area just precede these epochs, and the times of maxima are shown by the vertical continuous lines drawn in a similar manner. To show the probable times of the recurrence of these epochs during a portion of the next great period of thirty-five years two vertical lines have been inserted at the years 1903, which is the probable epoch of the next great maximum, and 1913, the following minimum, so that their relation to the probable variation of rainfall, as indicated by the dotted portions of the curves, can be seen at a glance.

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In conclusion, attention may be drawn to the fact that during the last few years a far more close connection between solar and meteorological phenomena has been made out than was the case some years ago, and since this long period rainfall cycle synchronises so well with the solar changes, the latter may render valuable assistance in determining the epochs of these dry and wet cycles.

WILLIAM J. S. LOCKYER.

ETIOLATION.¹

THIS monograph is published by the aid of the Daly Lydig fund bequeathed by Charles P. Daly, and embodies the results of the author's investigations extending from 1893 to 1902, and one of the first questions it arouses is, to what extent is this sustained experimental work stimulated by the certainty of adequate publication owing to the generosity of patriotic endowment, and to what extent does such work react on the pockets of friendly millionaires and induce the endowments for further work? In any case, Americans are fortunate in their circumstances in these respects.

The book, which comprises more than 300 pages of text and 176 figures, all admirably done, is divided into three principal sections. There is, first, a summary of the history of the subject, beginning with Ray (1686) and Hales (1727), and occupying 34 pages of more or less critical notes. It is, of course, impossible for us to verify the enormous number of the references to this part of the subject, but if the author has made many such blunders as those on pp. 27 and 29, where on two separate occasions he cites volumes and pages as from *Proc. Roy. Soc.* when he should have written *Philosophical Transactions*, the value of his bibliography must suffer. If a leading American plant physiologist does not know the difference between the two publications referred to, it is time he did; if he *does*, the inference that he has not consulted the original memoirs is as inevitable as it is dispiriting.

The second chief division of the work occupies the bulk of the book, pp. 35-200, and reflects credit on the author and his pupils for their industry and clearness of description, as well as for the interesting choice of plants selected for experiment. These include not only ordinary flowering plants, but also more out of the way forms of monocotyledons and dicotyledons, as well as ferns, *Equisetum*, &c. The one note of disappointment in this portion of the book will be struck by the want of plan. Numbers of most interesting observations on the behaviour of particular species in the dark, and illustrations of their facies, their anatomy compared with that of normal plants, their curves of growth and so forth will make the book useful to all investigators; but the plants are arranged in alphabetical order, and when the reader turns to a particular species he has no guide as to how it will be treated. Thus, taking at random *Salvia*, *Sansevieria*, *Sarracenia*, *Saururus*, and *Sparaxis*, which follow in the order given on pp. 171-180. The first merely heads a small paragraph stating that the corolla is atrophied in darkness. Under *Sansevieria* the etiolation of the shoot is described only in so far as external changes are concerned. In *Sarracenia* the effects of etiolation on the histology of the epidermis lining the "pitchers" are well illustrated. In *Saururus* figures of the anatomy of etiolated and normal stems, and measurements of height and thick-

¹ "The Influence of Light and Darkness upon Growth and Development." By D. T. Macdougall, Ph.D., Mem. New York Bot. Garden, Vol. ii. Pp. xiii + 319. (1903.)

ness form the theme; while Sparaxis heads a short paragraph recording failure of growth.

All this suggests a heterogeneous collection of student's notes as the groundwork of the memoir, and interesting and useful as many of these are, they might have been rendered more valuable by classification and efficient editing.

The third portion of the book is occupied with general considerations, and embraces summaries of the foregoing, theories as to the nature of etiolation, and so forth.

Here, of course, we look for the author's own views, but with the exception of vague statements here and there, the concluding portions of the book force us reluctantly to decide that, important and interesting as the memoir is, it is so not so much as a work of original thought and suggestion, but as an extensive and more or less critical survey of what others have done. In this category it stands well, and may be recommended, but we do not like such sentences as the following exercise for the grammarian and the physicist:—

"It is, of course, entirely probable that the action of light may set up chemical processes in the plant in a manner entirely stimulative, and independent of any communication or transormation of energy" (p. 201).

PROF. J. WILLARD GIBBS.

THE announcement of the death of Prof. J. Willard Gibbs, of Yale University, will be received with the deepest regret by the whole of the scientific world.

There are few workers who have done so much as Prof. Willard Gibbs to teach the lesson that it is to the mathematician that the experimentalist must look for new ideas. The papers which have made his name famous date from 1873, when he published in the *Transactions* of the Connecticut Academy his paper on the geometrical representation of the thermodynamical properties of bodies. Gibbs first discussed the advantages of using different thermodynamical variables for graphic representation, and then discussed the surface formed by taking as coordinates the volume, entropy and energy of a body. "Gibbs's thermodynamical model," or "thermodynamic surface" as it is now called, has become best known to English readers through the account given in Maxwell's "Theory of Heat." The study of the properties of thermodynamical surfaces has afforded a wide field of research, which is still continuing to yield new results in the hands of the Dutch school of physico-chemists. A remarkable feature of the investigation is the geometric representation of the conditions of thermodynamic stability, which does much to remove the difficulties attaching to any algebraic form of enunciation. A further paper, entitled "Graphic Methods in the Thermodynamics of Fluids," was published in 1878.

Gibbs's epoch-making papers *par excellence* are, however, those dealing with the equilibrium of heterogeneous systems, the first of which, dealing with chemical phenomena, was published in June, 1876, while the second, dealing with capillarity and electricity, appeared in July, 1878. The most essential feature of Gibbs's discoveries consists in the extension of the notion of the thermodynamical potential to mixtures consisting of a number of different components, and the establishment of the properties that this potential is a linear function of certain quantities which Gibbs has called the potentials of the com-

ponents, and that where the same component is present in different phases which remain in equilibrium with each other, its potential is the same in all the phases, besides which the pressures and temperatures of the phases are equal.

The importance of these results was not realised for a considerable time. It was difficult for the experimentalist to appreciate a memoir in which the treatment is highly mathematical and theoretical, and in which but little attempt is made to reduce conclusions to the language of the chemist; moreover, it is not unnatural to find the pioneer dwelling at considerable length on comparatively infertile regions of the newly-explored territory, while points of vantage which have subsequently proved to be the most productive fields of study were dismissed very briefly. It was largely due to Prof. van der Waals that two new and important fundamental laws were discovered in the paper, namely, the phase rule and the law of critical states, and the consequences of the first of these laws were the subject of remarkable developments in the hands of Bakhuis Roozboom, Schreinemakers, Stortebeker and Wilder Bancroft. The well-cultivated tracts of knowledge which represent a most important branch of modern physical chemistry bear but little resemblance to the crude, often circuitous path, full of stumbling blocks and difficult obstacles by which Gibbs first opened up this region. The study of dissociation phenomena has afforded some of the most beautiful experimental verifications of Gibbs's theories, which have done much to convert theoretical chemistry into a branch of applied mathematics.

It is not the physicist and chemist alone who are indebted to Prof. Gibbs; he has also made his mark among mathematicians in connection with the study of quaternions and vector algebra. Physicists claim that in the Hamiltonian system of quaternions there is a loss of naturalness from the fact that the square of a vector becomes negative. Gibbs met the objection by suggesting an algebra of vectors with a new notation, the expression for the product of two vectors being formed in such a way as to give a positive value for the square of a vector. His paper on "Multiple Algebra" was published in the *Proceedings* of the American Association for 1886.

Gibbs's attention has recently been turned to re-modelling the mathematical theories underlying the kinetic theory of gases, and the law of partition of energy. His work on statistical mechanics has been before us for about a year, but so difficult is the subject that a considerable further time must elapse before it can be widely understood and appreciated. His interpretation of the determinantal equation as the principle of conservation of extension in phase, his methods of dealing with ensembles of systems, and his establishment of the existence of irreversible phenomena in connection with such ensembles are all distinct advances, but in connection with the last-named properties an idea necessarily forces itself on one that there must be some assumption underlying the proof which might with advantage be discussed more explicitly than was done in the treatise in question, and his loss at the present time deprives us of the prospect of further enlightenment on difficulties which no amount of mere mathematical formulæ will clear up.

As mentioned last week, he was elected Foreign Member of the Royal Society in 1897, and received the Copley medal in 1901. He was also an honorary or corresponding member of the British Association, the Cambridge Philosophical Society, and many other learned societies both in this country and abroad.

G. H. B.